A Section 508–conformant HTML version of this article
is available at https://doi.org/10.1289/EHP10414.

Ambient Air Pollution Exposure among Individuals Experiencing Unsheltered Homelessness

Maeve G. MacMurdo,[1] *Karen B. Mulloy,*[2] *Charles W. Felix,*[3] *Andrew J. Curtis,*[2] *Jayakrishnan Ajayakumar,*[2] *and Jacqueline Curtis*[2]

[1]Respiratory Institute, Cleveland Clinic, Cleveland, Ohio, USA
[2]Department of Population Health Sciences, School of Medicine, Case Western Reserve University, Cleveland, Ohio, USA
[3]Tulare County Counsel, Visalia, California, USA

https://doi.org/10.1289/EHP10414

Introduction

Exposure to ambient air pollution is increasingly recognized as a major driver of morbidity and mortality.[1] Ambient air pollution is anticipated to increase as a result of climate change, extreme weather events and wildfires.[2,3] Within the United States, disparities already exist in exposure to air pollution. Residing in a non-white majority or low-income census tract is associated with increased exposure to fine particulate matter [PM ≤ 2.5 μm in aerodynamic diameter ($PM_{2.5}$)].[4] The pattern of air pollution exposure among other vulnerable populations has yet to be established.

Individuals experiencing homelessness represent a growing population in the United States, with over half a million people homeless in 2020.[5] Among this group, an increasing proportion experience unsheltered homelessness—defined as residence in the street or in a structure not intended for human habitation.[6] These individuals are uniquely vulnerable to the impact of worsening air quality, particularly outside of large urban centers, where access to indoor shelters may be limited.[7]

We hypothesize that in addition to global air pollution, individuals experiencing unsheltered homelessness are exposed to excess air pollution as a result of proximity to stationary and mobile sources. By considering this potential exposure at the local level, our aim was to provide a broad estimate of exposure, and develop a framework of local-level geospatial analysis that can be used to guide further targeted research and intervention.

Methods

In collaboration with Tulare County Health and Human Services Agency, individuals experiencing unsheltered homelessness were invited to participate in a local knowledge mapping (LKM) survey. Participants were asked to map places of importance to them on a printed base map, with focus on "safe" spaces where they had spent >1 month over the preceding year. Safety was self-defined by participants, and an explanation provided by the participant for each site. Location data was subsequently digitized and mapped at the point level using ArcMap (version 10.7.1; ESRI). Emitters were categorized by major emitter group [PM, organic gas emissions (total organic gases, TOG)], nitrous oxides (NO_x) and sulfur oxides (SO). At the suggestion of local homeless service providers, participants were compensated with $5 gift cards for McDonalds or with bus passes. This study was approved by the Case Western Reserve University Institutional Review Board (No. 20191570). Informed consent was obtained verbally using a provided script.

Stationary source emission exposure was estimated using California Air Resource Board (CARB) stationary source emission data.[8] Mobile source emissions across the 2019 calendar year were estimated using the CARB 2021 EMissions FACtors (EmFAC) modeling system.[9] This system provides a county-level estimate of roadway-associated emission modeled for aggregate levels of road speed and seasonal temperature and traffic variation. Mean emissions of ($PM_{2.5}$), PM ≤ 10 μm in aerodynamic diameter (PM_{10}), TOG, NO_x, and SO were estimated in tons per year.

Three hundred-meter and 1,000-m buffers were generated around stationary emitters and roadways. Using spatial joining, the number of individuals experiencing homelessness whose day or nighttime locations fell within these buffers was calculated at each geographic level, stratified by emission type and location.

Results

A total of 62 individuals experiencing homelessness participated. The majority of participants (68.9%) had resided in Tulare County for more than 10 y. More than half (59.2%) self-identified as female, with 49.2% of participants falling between 45 and 65 years of age. Participants identified a total of 166 locations where they spent the night during the 2019 calendar year and a further 117 "safe" day locations. Fifty-six percent of "safe" day locations intersected with "safe" night locations.

When analyzed by proximity buffer, 32.5% of night locations and 52.1% of day locations were within 300 m of a major roadway. Mobile emissions modeling for the 2019 calendar year estimated total road traffic-related emissions of $PM_{2.5}$ at 93.9 tons/y, with a further 190.5 tons/y of road traffic-related PM_{10} emissions. Total roadway-associated nitrogen dioxide (NO_2) emissions were estimated at 186.3 tons/y, with 1541.9 tons/y of TOG emission and 24.5 tons/y of SO_2 emissions.

In all, 891 registered stationary emitters were identified within Tulare County. Proximity of both day and night locations to stationary emitters was common throughout the county (Table 1).

Discussion

Individuals experiencing chronic unsheltered homelessness are exposed to a range of sources of air pollution, extending beyond the exposures captured by ambient air pollution monitoring. Within our sample, >50% of participants reported spending their daytime hours in close proximity to major roadways. Near roadway proximity has been associated with an increased risk of respiratory and cardiovascular disease across multiple cohorts.[10] Proximity to emission sources was also common. Reliance on stationary ambient monitor data may underestimate both potential airborne pollutant exposure and health impacts associated with exposure to these pollutants for this population.

Local knowledge mapping survey techniques represents a low-cost and easily reproducible mechanism to capture activity patterns among individuals exposed to air pollution. When combined with

Address correspondence to Maeve G. MacMurdo, Respiratory Institute, 9500 Euclid Ave., A90, Cleveland, OH 44195 USA. Telephone: (216) 633-5863. Email: macmurm@ccf.org

The authors declare they have nothing to disclose.

Table 1. Percentage of "safe" day and night locations in a 300- and 1,000-m proximity to stationary emitters across Tulare county by site of point in a time–count magnet event.

Primary emitter type and proximity		Tulare: Day locations [($n = 36$) %]	Tulare: Night locations [($n = 87$) %]	Visalia: Day locations [($n = 61$) %]	Visalia: Night locations [($n = 55$) %]	Porterville: Day locations [($n = 20$) %]	Porterville: Night locations [($n = 24$) %]
PMT emitter	<300 m	11.0	21.8	32.8	36.3	35.0	8.3
	<1,000 m	80.5	80.4	95.0	89	85.0	66.6
NO_x emitter	<300 m	16.7	20.6	14.8	21.8	65.0	41.6
	<1,000 m	30.6	37.9	59.0	43.6	100	95.8
SO emitter	<300 m	27.8	29.9	36.0	40.0	40	25.0
	<1,000 m	88.9	89.7	98.3	98.2	90	70.8
TOG emitter	<300 m	58.3	49.4	70.5	60.0	55.0	41.7
	<1,000 m	97.2	95.4	98.3	98.2	100	95.8

Note: NO_x, nitrous oxide; PMT, total particulate matter; SO, sulfur oxides; TOG, total organic gases.

local spatial data, this can provide guidance regarding further monitoring and policy interventions at a geographically granular level.

References

1. Lelieveld J, Evans JS, Fnais M, Giannadaki D, Pozzer A. 2015. The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature 525(7569):367–371, PMID: 26381985, https://doi.org/10.1038/nature15371.
2. Hong C, Zhang Q, Zhang Y, Davis SJ, Tong D, Zheng Y, et al. 2019. Impacts of climate change on future air quality and human health in China. Proc Natl Acad Sci USA 116(35):17193–17200, PMID: 31405979, https://doi.org/10.1073/pnas.1812881116.
3. Liu JC, Mickley LJ, Sulprizio MP, Dominici F, Yue X, Ebisu K, et al. 2016. Particulate air pollution from wildfires in the Western US under climate change. Clim Change 138(3):655–666, PMID: 28642628, https://doi.org/10.1007/s10584-016-1762-6.
4. Colmer J, Hardman I, Shimshack J, Voorheis J. 2020. Disparities in $PM_{2.5}$ air pollution in the United States. Science 369(6503):575–578, PMID: 32732425, https://doi.org/10.1126/science.aaz9353.
5. National Alliance to End Homelessness. 2020. 2020 Edition - National Alliance to End Homelessness. https://endhomelessness.org/homelessness-in-america/homelessness-statistics/state-of-homelessness-2020/ [accessed 27 July 2021].
6. HUD Exchange. 2018. 2018 AHAR: Part 1 - PIT Estimates of Homelessness in the U.S. Published online December 2018. https://www.hudexchange.info/resource/5783/2018-ahar-part-1-pit-estimates-of-homelessness-in-the-us/ [accessed 11 April 2021].
7. Health Resources and Services Administration. 2014. Homelessness in Rural America. Policy brief. July 2014. National Advisory Committee on Rural Health and Human Services. https://www.hrsa.gov/sites/default/files/hrsa/advisory-committees/rural/publications/2014-homelessness.pdf [accessed 4 August 2021].
8. California Air Resource Board. Fact sheet #1: development of organic emission estimates for California's emission inventory and air quality models. Published online August 2020. https://ww2.arb.ca.gov/sites/default/files/2021-08/emfac2021_technical_documentation_april2021.pdf [accessed 17 August 2021].
9. California Air Resources Board. n.d. EMFAC [Website]. https://arb.ca.gov/emfac/ [accessed 27 July 2021].
10. Suglia SF, Gryparis A, Schwartz J, Wright RJ. 2008. Association between traffic-related black carbon exposure and lung function among urban women. Environ Health Perspect 116(10):1333–1337, PMID: 18941574, https://doi.org/10.1289/ehp.11223.